11 *Egypt. J. Vet. Sci.* **Vol. 56, (Special issue),** pp. 99-108 (2025)

Egyptian Journal of Veterinary Sciences
https://ejvs.journals.ekb.eg/

Anatomical Investigation of The Swim Bladder in Grass Carp *(Ctenopharyngodon idella)* and Red Sea Halfbeak *(Hyporhamphus gamberur)* Fish Using Different Imaging Techniques

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Abstract

THE CURRENT study elucidated the gross anatomical description of the swim bladder in 10 fish from each species (grass carp and Red Sea halfbeak), with further X-ray, computed tomography, and ultrasonographic examinations. The study revealed that the swim bladder of the two examined species had significant differences. The swim bladder of the Red Sea halfbeak was vesicular, while the bladder of the grass carp was composed of two chambers (anterior and posterior). The characteristic arrangement of the vesicles on the surface of the Red Sea halfbeak swim bladder resembled a pearl necklace or soap bubbles. The grass carp had a connection between the swim bladder and the esophagus via a pneumatic duct, so it is considered to be of the physostomous type. In contrast, the Red Sea halfbeak fish's bladder lacked this duct but had a large blood vessel in the cranioventral extremity and a smaller one in the caudodorsal extremity, making it of the physoclistous type. The plain radiography and computed tomography revealed the grass carp's swim bladder as two radiolucent structures of different sizes, with a constriction (isthmus) in between. The study highlights the typical features of the swim bladder in two different species of fish for a better understanding of fish anatomy and possible swim bladder disorders.

Keywords: Swim bladder, Grass carp, Red Sea halfbeak, X-ray, computed tomography.

Introduction

Grass carp *(Ctenopharyngodon idella)* are a widely farmed species of freshwater fish in China [1] and are cultured in 40 countries around the world. The main producers of grass carp include China, Bangladesh, Taiwan, Iran, and the Russian Federation [2]. The halfbeak (*Hemiramphus* spp., Family: Hemiramphidae) is a fish species found worldwide. While most species of halfbeaks are marine, some are found in freshwater [3]. Halfbeaks are omnivores [4], with adults primarily feeding on seaweed, while the younger fish mainly consume zooplankton, green algae, and diatoms [5].

The swim bladder, gas bladder or air bladder was a characteristic glistening hollow sac in fish. It was located between the kidneys and alimentary tract in the abdomen. The swim bladder might be one or two chambers with a constriction. There were two types of swim bladder; open or physostomous and closed or physoclistous. In physostomous type, the bladder was connected to the esophagus by a pneumatic duct. While in physoclistous type, the bladder was closed and lacked connection with the esophagus [6].

The gas bladder possessed pressure receptors in its wall that aids in balanced buoyancy in fish, i.e. the capability to consume minimum energy at certain water levels via the inflation and deflation of the gas bladder due to variable pressures of gas [7, 8]. The swim bladder had a vital role in communication between fishes through production of sound by muscles [9]. There were link between the inner ear and the gas bladder, thus the hearing capability of carps and catfishes was better than fish that lacked Weberian apparatus [10, 11]. In certain teleost fish, the mechanical and sensory function of lateral line system is enhanced by the connection amongst the swim bladder and the lateral line [12, 13].

The wall of anterior swim bladder chamber of silver carps was thick, rich in collagen, and having a larger surface area. Fish collagen is analogous to that

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(Received 09 March 2025, accepted 16 April 2025)
DOI: 10.21608/ejvs.2025.366937.2687
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of human, and constitutes a component of ligaments, tendons, tissues, organs, skin and bones. Thus, fish Collagen can be utilized in human medical application essential for regeneration of tissues, healing of wounds, elasticity of skin, and moreover prevents tearing of tissues [14, 15]. The previous study on the anatomy of the swim bladder in grass carp lacked description in detail [1]. Hitherto, the anatomy of air bladder of the Red Sea halfbeak had not been described until now. The structure-functional diversity and uses of the swim bladder as it relates to recent applications for the manufacturing of several types of medical products (fish collagen and gelatin) and devices (vascular scaffolds and medical plates), making the study of the swim bladder in grass carp and Red Sea halfbeak very interesting. Furthermore, the current investigation will be helpful in recognition of any air bladder disorders, and contribute to further studies on fish anatomy.

Material and Methods

Fish

Ten apparently healthy adult fish of both sexes from two species; grass carp *(Ctenopharyngodon idella)* and Red Sea halfbeak *(Hyporhamphus gamberur)* were used in this study. Grass carp fresh fish were purchased from the fish markets, while Red Sea halfbeak fish were caught from the Red Sea.

Gross Anatomical Examination

The trunk of both sexes of the two fish species was dissected ventrally, and the lateral abdominal wall was removed to expose the swim bladder in its normal position in relation to the surrounding organs. The gonad, alimentary tract and the surrounding fat were removed to expose the pneumatic duct of the swim bladder. Photographs of the fish, air bladder, and its duct were taken in situ and after removal, separately, using a 32-megapixel Sony DSC-W690 digital camera. The swim bladder of the grass carp was cut, opened and examined to identify the opening of the pneumatic duct. The swim bladder of the Red Sea halfbeak was injected with white gum milk (Latex 60%) for corrosion casting. They were opened and photographed with a stereomicroscope (x4: x10) for demonstration of the interior septa and blood vessels. The lengths and widths of the swim bladder were measured using a ruler and an X-ray machine.

Radiographic examination, Computed tomography and Ultrasound scanning

Plain Radiographic examination

All the examined fish of the two species were radiographically examined with an X-ray machine (Pox-300 BT, Toshiba, Rotanode™, Japan) using 45-70 kV and 8- 12 mA. Two radiographic views were taken from each examined fish: a laterolateral (LL) view was obtained with each fish placed in lateral recumbency, and a dorsoventral (DV) view was taken through ventral recumbency.

Computed tomography scanning

All examined fish were scanned using computed tomography (CT) (Hitachi, USA, Multislice 16 scanner) at 120 kV and 50 mA for 0.8 sec with a 5 mm thickness. Images of the examined fish were presented in the sagittal, coronal, and transverse axes.

Ultrasonographic imaging of right laterally recumbent fish was performed using an ultrasound machine (Esaote MyLab One, Italy) with a superficial 6 MHz linear transducer to describe the echogenicity of the swim bladder.

Results

A. Grass Carp (Ctenopharyngodon idella)

The plain X-ray of the swim bladder of the grass carp showed two separate radiolucent chambers with clear outlines. It gives homogenous radiographic shadow under the vertebral column and the shadow of the ribs was projected onto it, and its size was proportional to the fish body size. The three different axes of the CT revealed the swim bladder as two radiolucent structures of different sizes with a constriction (isthmus) in between. The anterior part was larger than the posterior (caudal) part. The plain radiography and CT revealed that the site of the swim bladder extends from the 1st to the 22nd vertebra (anterior from 1 to 15, posterior from 16 to 22). The ultrasonographic image showed two sacs of unequal size enclosing an echogenic area.

The swim bladder of the grass carp was situated ventral to the kidney and vertebrae, dorsal to the internal organs, and it was easily detachable from the surrounding organs. The two swim bladder compartments occupied almost the entire length and breadth of the body cavity. The anterior part of the gas bladder in female grass carp was larger than the posterior part, approximately about two-thirds of the bladder's size in females, and vice versa in males. The anterior compartment had a rounded cranial end that adjoined the septum transversum. It measured approximately 7.24 cm in length and 3.42 cm in width. The posterior compartment was narrow with a tapering caudal end. It was about 4.14 cm in length and 1.53 cm in width (Fig. 1 A-J).

The swim bladder was a wide, white, membranous sac with a smooth, shiny external surface and an asymmetrical thick wall. Internally, it showed a smooth, even surface with light longitudinal striations that were more pronounced in the thicker areas. The chambers of the swim bladder lacked internal septa and communicated through a narrow internal opening surrounded by an elevated ridge. The bladder was connected to the esophagus via a pneumatic duct (*ductus pneumaticus*), having the *physostomous* type. The duct originated from the cranioventral aspect of the posterior chamber and extended rostrally between the bladder and the internal viscera. It then ran parallel to the liver, passed through a thin, transparent transverse membrane (*septum transversum*), and swelled into a pneumatic bulb before ending on the dorsal aspect of the esophagus (Fig. 2 A-J).

B. Red Sea halfbeak (Hyporhamphus gamberur)

All the different diagnostic imaging techniques used in the examination of the Red Sea halfbeak fish showed the vesicular appearance of the swim bladder. These vesicles were clearly noted in the lateral view of the radiographic image and the sagittal axis of computed tomography. The swim bladder appeared as a radiolucent structure located between the 5th and 33rd vertebra. It was seen ultrasonographically as an anechoic structure with distal enhancement. The swim bladder occupied the dorsal part of the peritoneal cavity, firmly enclosed by dark peritoneum. The swim bladder measured approximately 12.45 cm in length and 1.02 cm in width (Fig. 3 A-G).

The swim bladder was transparent and consisted of a matrix of air-filled, thin-walled, small vesicles, which were 3-5 layers deep and 3–5 mm in diameter for each vesicle. The length of each vesicle was about 10 mm. The vesicles had variable shapes; they were predominantly polygonal, with quadrilateral and pentagonal sides. The characteristic arrangement of the vesicles on the surface of the swim bladder resembled a pearl necklace or soap bubbles. The anterior extremity of the swim bladder had three projections (horns): right, middle, and left, while the posterior extremity was sharp. The anterior left horn was the smallest. The swim bladder remained inflated even after its removal from the body cavity. The internal surface of the bladder, when opened, had a characteristic appearance, reminiscent of a honeycomb, or pockets. Each vesicle has its own cavity and separated from the others by differently sized longitudinal and transverse septa. Therefore, piercing one vesicle will not collapse the neighboring vesicles. The vascularization of the swim bladder appeared at both extremities: a large blood vessel was observed in the cranioventral extremity, and a smaller one was noticed in the caudodorsal extremity, classifying it as the physoclistous type (Fig. 4 A-J).

<u>Discussion</u>

Cartilaginous fishes, such as sharks, and fast-swimming fishes, like the tuna and mackerel families, often lack a swim bladder [16]. On the other hand, the swim bladder had unique and essential features in each studied species. Regarding its position, it was located dorsally over the internal organs and was easily detached from these organs in grass carp. A parallel observation was made in Russian sturgeon, American paddlefish, and common carp. The gas bladder adjoins the kidney on one side and the dorsal part of the pleuroperitoneal cavity on the other side in zander, rainbow trout, and northern pike [17]. The latter author added that in zander, the bladder is located near the caudal skull and inner ears, which contributes to high auditory sensitivity. However, Kardong [16] reported that the carp swim bladder is not connected to the inner ear. The greater the extension of the swim bladder cranially, the greater the hearing sensitivity, as in most species; cichlids (Perciformes), Gerreidae (Eucinostomus argenteus), Mormyridae and a teleost (E. maculatus) [18, 19, 20, 21]. In the present study, the bladder in grass carp was placed more anteriorly than in the Red Sea halfbeak. Therefore, the Red Sea halfbeak fish lived near the surface of the water and was easier to catch than grass carp. Cartilaginous fishes, such as sharks, and fast-swimming fishes, like the tuna and mackerel families, often lack a swim bladder [16]. On the other hand, the swim bladder had unique and essential features in each studied species. Regarding its position, it was located dorsally over the internal organs and was easily detached from these organs in grass carp. A parallel observation was made in Russian sturgeon, American paddlefish, and common carp. The gas bladder adjoins the kidney on one side and the dorsal part of the pleuroperitoneal cavity on the other side in zander, rainbow trout, and northern pike [17]. The latter author added that in zander, the bladder is located near the caudal skull and inner ears, which contributes to high auditory sensitivity. However, Kardong [16] reported that the carp swim bladder is not connected to the inner ear. The greater the extension of the swim bladder cranially, the greater the hearing sensitivity, as in most species; cichlids (Perciformes), Gerreidae (Eucinostomus argenteus), Mormyridae and a teleost (E. maculatus) [18, 19, 20, 21]. In the present study, the bladder in grass carp was placed more anteriorly than in the Red Sea halfbeak. Therefore, the Red Sea halfbeak fish lived near the surface of the water and was easier to catch than grass carp.

The swim bladder of the grass carp extended from the 1st to the 22nd vertebrae, while in the Red Sea halfbeak, it was located between the 5th and 33rd vertebrae. In *Laguvia ribeiroi*, the air bladder is found in two lateral pouches in the anterior half of the body, with a bony element in between. Moreover, in *Ailia coila*, it is transversely placed on the ventral surface of the vertebral column, corresponding to the 3^{rd} to 5^{th} vertebrae. In *Clupisoma garua*, it is positioned longitudinally, adjacent to a few anterior vertebrae. Furthermore, in *Eutropiichthys vacha* and *Pseudeutropius atherinoides*, the swim bladder is reinforced anteriorly by bony vertebral elements [22].

The air bladder consists of one chamber in Russian sturgeon, American paddlefish, rainbow trout, northern pike, and zander [17], as well as in *Ailia coila*, and *Mystus cavasius* [22]. The gas bladder in *Laguvia ribeiroi* [22], *Astatotilapia burtoni* [23], Nile tilapia (*Oreochromis niloticus*) [24], and common carp (*Cyprinus carpio*) [17, 25] consists of double chambers, with ductus communicans connecting them through a constriction, which agrees with our results in grass carp. Additionally, Farag et al. [25] referred to the narrow constriction as isthmus. In Nile tilapia [24] and *Astatotilapia burtoni* [23], the anterior and posterior chambers are separated by a diaphragm that is perforated by a sphincter containing circular and radiating muscle fibers, suggesting that it may likely allows the movement of gas between the two parts. On the other hand, the swim bladder of the Red Sea halfbeak was vesicular. A similar result was observed in ten species of *Hemiramphus* [26].

The cranial chamber of the swim bladder was larger in size, and ended in contact with the septum transversum. While the caudal chamber was smaller and narrower in common carp [25], which is in agreement with our results in grass carp. Moreover, the larger anterior partition of *Astatotilapia burtoni* was bilobate anteriorly, with one lobe on either side of the vertebral column, and extended close to the neurocranium [23].

The swim bladder has variable shapes, depending on the shape of the fish and its mode of life, swimming behaviour, and hearing sensitivity. The gas bladder in zander is tube-like; in rainbow trout, it has a pearl necklace shape; in American paddlefish, it is even round caudally; and in Russian sturgeon, it has a rounded, elongated end [17]. In most species of *Centromochlus*, it is nearly apple-shaped [27]. The swim bladder is heart-shaped in *Ompok bimaculatus*, *Wallago attu*, and *Mystus cavasius*; somewhat rectangular in *Rita rita*; horseshoe-shaped in *Ailia coila*; bean or kidney-shaped in *Laguvia ribeiroi ribeiroi*; resembles a maize grain in *Clupisoma garua*; and has a circular loop, necklace-like structure in *Eutropiichthys vacha*. In *Pseudeutropius atherinoides*, it is oval in shape [22].

Regarding the colour of the swim bladder, it is whitish-milky in *Laguvia ribeiroi*, *Ailia coila*, *Eutropiichthys vacha*, and *Mystus cavasius*. It is brownish-white in *Clupisoma garua*, and in *Pseudeutropius atherinoides*, it is pale brown [22]. The wall of the swim bladder of rainbow trout is very thin, whereas in the Russian sturgeon and American paddlefish, it is thicker [17]. In most species of Auchenipterids, the bladder has smooth, simple walls; in contrast, species of *Ageneiosus*, it has a partially or completely ossified wall [27]. In *Mystus cavasius* and *Pseudeutropius atherinoides*, the swim bladder is thick-walled. The bladder is constructed of fibrous muscles in *Eutropiichthys vacha* [22]. In goldfish, the wall of the posterior chamber is thicker [28].

Internally, the Red Sea halfbeak swim bladder had longitudinal and transverse septa, while in the grass carp, it was devoid of any septa. The air bladder has T-shaped regular septa in *Cordiform*. In *Ompok bimaculatus* and *Wallago attu*, the septa are incomplete and intercommunicate, dividing the bladder into three compartments. In *Mystus cavasius*, the swim bladder has four parts, separated by longitudinal and transverse septa. However, the compartments in *Rita rita* consist of three, divided by secondary incomplete septa. In *Pseudeutropius atherinoides*, the bladder shows 4-5 short, incomplete transverse septa and one longitudinal septum [22]. In common carp, they are not divided internally by any septa [25].

The swim bladder of the Red Sea halfbeak showed three horns at the anterior extremity. On the other hand, *Asterophysus batrachus* has diverticula surrounding the whole bladder but lacks them ventrally and dorsally. Similarly, *Tocantinsia trachycorystes*, *T. ceratophysus*, *T. porosus*, *T. galeatus*, and *T. piresi* have a couple of diverticula, which are bubble-like in the latter species. Additionally, *T. striatulus* has short posterior diverticula. On the other hand, *T. coriaceus* lacks any diverticula [27]. In *Rita rita*, a pair of diverticula arises from its caudal angles, while in *Mystus cavasius*, there is a pair of small, curved horns on the anterior corners of the bladder [22]. In the mojarra fishes, the swim bladder forms two bilateral horns connected to the inner ear, playing a role in enhancing hearing [29].

Concerning the mechanism of swim bladder deflation, it differs according to its type. In physostomous species, the excess gas can be removed from the air bladder through the sphincter of a duct which connects the esophagus and the swim bladder, as in the common carp [17, 25], *Ompok bimaculatus*, *Wallago attu*, *M. cavasius*, *Rita rita*, and *Laguvia ribeiroi* [22]. The swim bladder of the grass carp was of the physostomous type. Otherwise, in a physoclistous bladder, gas resorption occurs by simple diffusion into the bloodstream through a rete mirabile or gas gland area. The swim bladder of the Red Sea halfbeak was of the physoclistous type. The physoclist type usually passes through a physostome stage during its larval development [30]. There is an oval foramen located on the dorsal internal surface of the swim bladder [31]. It is believed that, in some cases, the swim bladder is a reduced-size, deeply placed organ with an absent rete mirabile and gas gland. As a result, there is no mechanism for filling, and it seems to lack hydrostatic function, as seen in *Ailia coila*, *Clupisoma garua*, *Eutropiichthys vacha*, and *Pseudeutropius atherinoides* [22].

In the common carp, the pneumatic duct originates from the cranioventral aspect of the posterior chamber and extends cranially to terminate at the dorsal aspect of the esophagus [25]. A similar observation was noticed in the grass carp. The gas bladder ducts of the American paddlefish, Russian sturgeon, rainbow trout, and northern pike are similar to those of the common carp, but they are shorter in length. This duct is narrow in the rainbow trout and northern pike, but wide and short in the Russian sturgeon and American paddlefish [17].

Diagnostic imaging in this study showed species related differences in the structure of swim bladder are well recognizable by different imaging techniques. The anatomical characteristics and apparent pathological changes of fish will be well documented using these methods. The obtained results conformed to the finding of fish dissection, and assessment of the fish position during radiographical examination. It was observed that the dorsoventral position provided less detail about the status of the swim bladder. This is because the vertebral column and ribs shadows were projected onto each other dividing the swim bladder on this view. This result was in agreement with that recorded in previous study [32]. The ultrasonographic image of the grass carp showed two sacs of unequal size enclosing an echogenic area with distal enhancement. This result related to the swim bladder changes that occurred after death as the examination was performed on preserved dead fish. After interpretation of different diagnostic imaging techniques, it can be stated that these methods are highly suitable for studying the swim bladder changes and useful for diagnostic investigations [32].

Conclusion

The current investigation demonstrated the gross anatomical description of the swim bladder in grass carp and Red Sea halfbeak, along with further plain X-ray, computed tomography, and ultrasonographic examinations. The swim bladder of the Red Sea halfbeak was vesicular, while the bladder of the grass carp was composed of two chambers (anterior and posterior). The grass carp swim bladder was of the physostomous type, while the bladder of the Red Sea halfbeak was of the physoclistous type. The plain radiography and computed tomography revealed the swim bladder as a radiolucent structure. The characteristics of the grass carp swim bladder wall suggest that future studies on the collagen and gelatin contents are needed, as it may be useful for the manufacturing of medical products.

Acknowledgments

We are grateful to the Anatomy and Embryology, Surgery, Anesthesiology, and Radiology Departments at the Faculty of Veterinary Medicine, Zagazig University, for supporting this work.

Funding statement

This study was not funded by any source.

Declaration of Conflict of Interest

The authors affirm that they have no conflicts of interest.

Ethical of approval

The protocol of this work was performed according to Zagazig University Institutional Animal Care and Use Committee, (ZU-IACUC/2/F/282/2023), Egypt.

Authors' contributions

Dr. Eman Mahdy and Dr. Eman El Behery gathered the specimens and conducted all the anatomical procedures. Dr. Shimaa Ezzeldein and Dr. Nehal Ibrahim handled various biomedical scanning methods. All authors contributed to data collection, article writing, data review and formatting, and gave their approval for the manuscript.

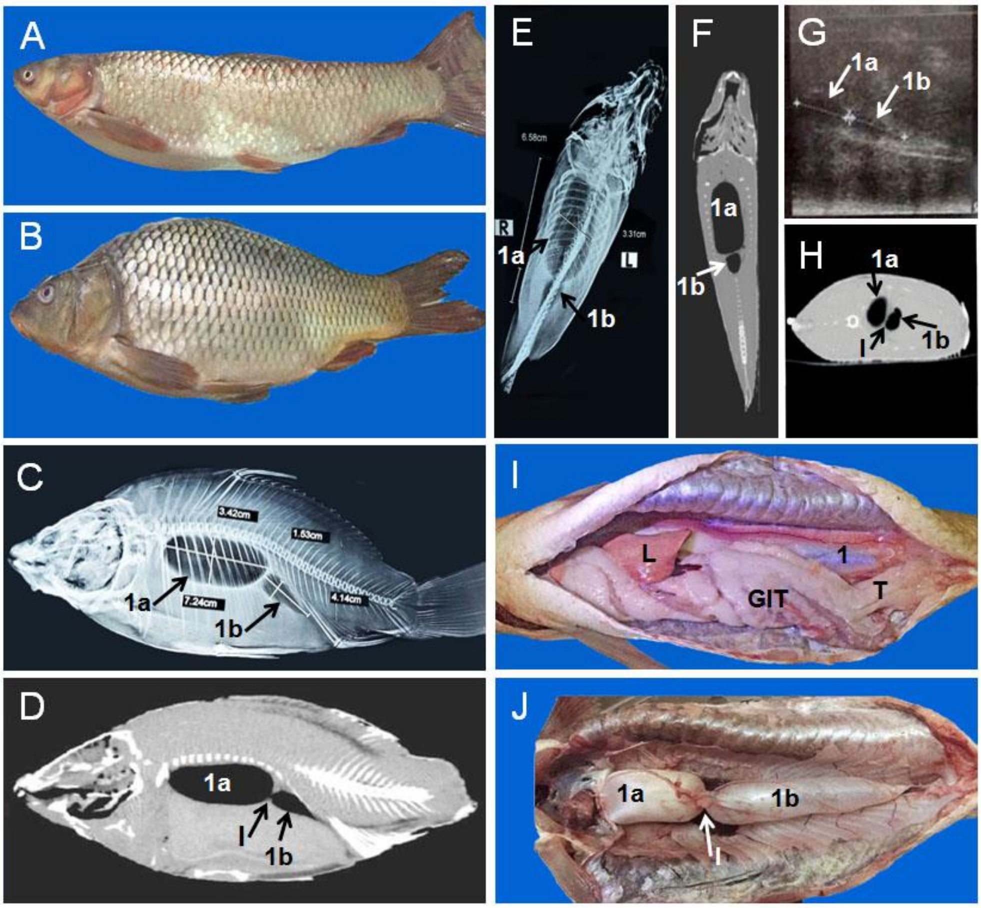

Fig. 1. Photographs of the grass carp (A male) and (B female). (C) Radiography (Lateral view) (D) Computed tomography (Sagittal scanning) (E) Radiography (Dorsoventral view) the shadow of the vertebral column appear dividing the sac into two parts, (F) Computed tomography (Coronal scanning), (G) Ultrasonographic image (Lateral view), (H) Computed tomography of the female grass carp (Transverse scanning) showing anterior chamber (1a), posterior chamber (1b) and Isthmus (I) of the swim bladder. (I) A photograph of the opened male grass carp (Left view) showing the viscera in situ: swim bladder (1), testis (T), liver (L), gastrointestinal tract (GIT). (J) A photograph of the anterior chamber (1a), posterior chamber (1b) and Isthmus (I) of the swim bladder of male grass carp in situ after removal of the surrounding organs.

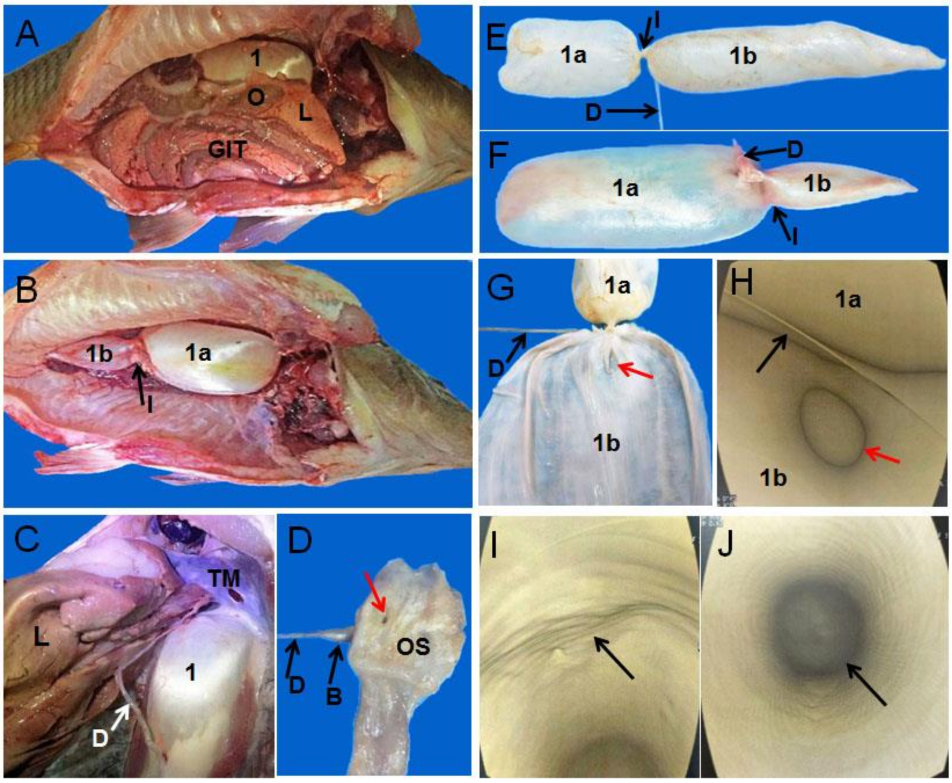

Fig. 2. (A) A photograph of the opened female grass carp (Right view) showing the viscera in situ: swim bladder (1), ovary (O), liver (L), gastrointestinal tract (GIT). (B) A photograph of the anterior chamber (1a), posterior chamber (1b) and Isthmus (I) of the swim bladder of female grass carp in situ after removal of the surrounding organs. (C) A photograph showing the pneumatic duct (D) of the swim bladder (1) penetrating the Transverse membrane (TM), liver (L). (D) A photograph showing the pneumatic duct (D) formed a pneumatic bulb (B) before its opening (arrow) in the esophagus (OS). Photographs of the removed swim bladder of male (E) and female (F) grass carp, showing the anterior chamber (1a), posterior chamber (1b), Isthmus (I) and pneumatic duct (D). (G) A photograph showing anterior chamber (1a), the opening (arrow) of the pneumatic duct (D) in the cranioventral aspect of the posterior chamber (1b) of the swim bladder. (H) Internal Computed tomography scan of the swim bladder of the grass carp showing an elevated ridge (black arrow) between the anterior chamber (1a) and posterior chamber (1b) and the opening (red arrow) of the pneumatic duct (origin). (I) Internal Computed tomography scan of the swim bladder of the grass carp showing some longitudinal striation in its wall (arrow). (J) Internal Computed tomography scan showing the anterior blind end (arrow) of the swim bladder of the grass carp.

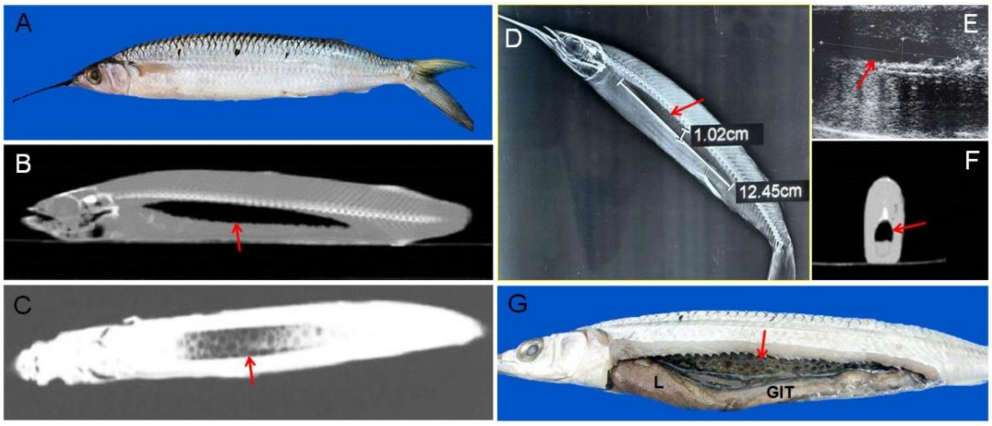

Fig. 3. (A) A Photograph of the Red Sea halfbeak. Computed tomography sagittal scanning (B) and coronal scanning (C), Radiography (Lateral view) (D), Ultrasonographic image (Lateral view) (E), Computed tomography of the Red Sea halfbeak (Transverse scanning) (F) showing the swim bladder (arrow). (G) A photograph of the opened Red Sea halfbeak (Left view) showing the swim bladder (arrow) in situ related to liver (L) and gastrointestinal tract (GIT).

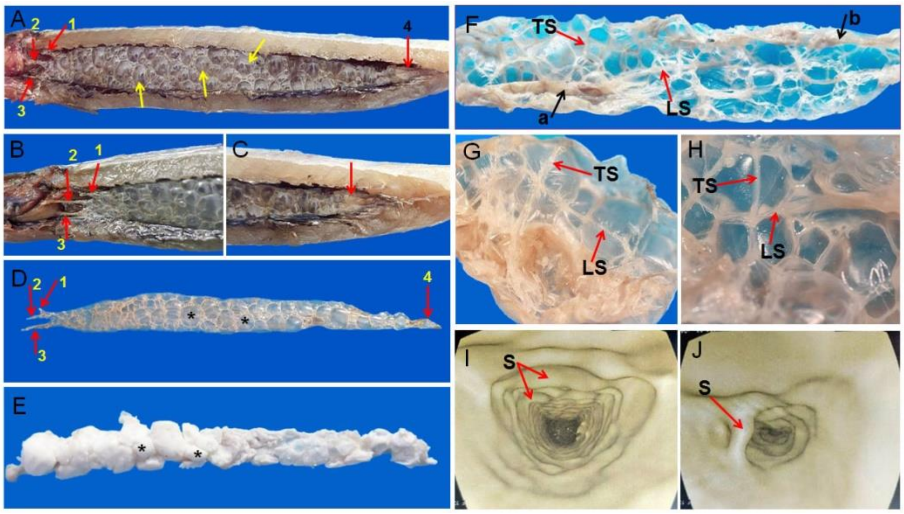

Fig. 4. Photographs of the Red Sea halfbeak (ventral view) (A), Higher magnification of the anterior (B) and posterior (C) parts of the fish with the vesicular swim bladder in situ after removal of the surrounding organs, the intact removed swim bladder (D) showing left horn (1), middle horn (2), right horn (3), narrow posterior end (4), large inflated vesicles (yellow arrows) and (asterisks *). (E) Cast corrosion of the vesicular (asterisks *) swim bladder. A photograph of the opened swim bladder of the Red Sea halfbeak (F), (G) higher magnification of (F), stereomicroscopic photo (H) showing anterior (a) and posterior (b) blood vessels, longitudinal (LS) and transverse (TS) septal walls of the vesicles. Internal Computed tomography scans of the swim bladder of the Red Sea halfbeak (I) and (J) showing the septa (S) forming the vesicles.

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الفحص التشريحي للمثانة الهوائية في سمك الكارب العشبي وسمك نصف المنقار (من البحرالأحمر) باستخدام تقنيات التصوير المختلفة

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الملخص

اهتمت الدراسة الحالية بالوصف التشريحي العام للمثانة الهوائية في عشرة أسماك من كل نوع (الكارب العشبي وسمك نصف المنقار(من البحر الأحمر)، مع إجراء فحوصات إضافية باستخدام الأشعة السينية، التصوير المقطعي المحوسب، والتصوير بالموجات فوق الصوتية. كشفت الدراسة أن المثانة الهوائية في النوعين المدروسين كانت تحتوي على اختلافات كبيرة. كانت المثانة الهوائية في سمك نصف المنقار كيسية الشكل، بينما كانت المثانة في الكارب العشبي مكونة من حجرتين (أمامية وخلفية). كان الترتيب المميز للحويصلات على سطح المثانة الهوائية لسمك نصف المنقار يشبه عقد اللؤلؤ أو فقاعات الصابون. كان هناك اتصال بين المثانة الهوائية و المريء عبر قناة هوائية في سمك الكارب العشبي، وبالتالي يعتبر من النوع الفيزيستوموس. في المقابل، كانت مثانة سمك نصف المنقار تفتقر إلى هذه القناة ولكنها تحتوي على وعاء دموي كبير في الطرف الأمامي البطني وآخر أصغر في الطرف الذيلي الظهري، مما يجعلها من النوع الفيزيكليستوس. أظهرت الأشعة السينية والتصوير المقطعي المحوسب المثانة الهوائية في الكارب العشبي على شكل جزئين شفافين بأحجام مختلفة، مع مضيق بينهما. تسلط الدراسة الضوء على الخصائص النموذجية للمثانة الهوائية في نوعين مختلفين من الأسماك لفهم أفضل لتشريح الأسماك والاضطرابات المحتملة في المثانة الهوائية.

الكلمات الدالة: المثانة الهوائية، الكارب العشبي، سمك نصف المنقار، الأشعة السينية، التصوير المقطعي المحوسب.